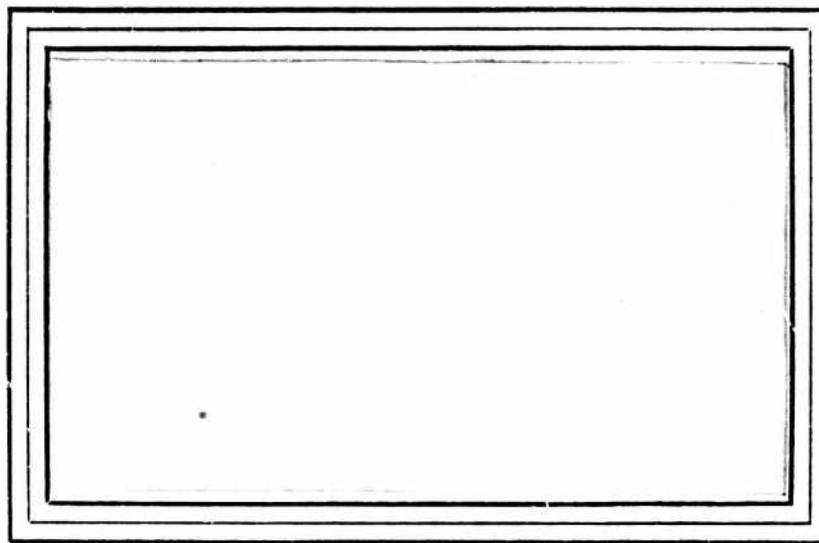


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RDTR No. 61
8 November 1966

A LITERATURE SEARCH FOR
CARTRIDGE CASE PLUG MATERIAL STUDIES

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This report is prepared under limited funding by ORD TASK SSO-002/323/R, Problem Assignment 9, dated 17 August 1966. The source of funds for this Problem Assignment is Funding Document 17X1319.7775 01 070, Sub Allotment B.

ABSTRACT

A comprehensive literature search has been carried out to determine whether plastic materials have been used in cartridge case plugs for semi-fixed ammunition and if so, which materials were studied and the results of those studies. Several military activities were visited and numerous personal interviews conducted in an effort to collect all pertinent information associated with cartridge case plug work. A synopsis of findings is given and references are made to applicable documents. Some of the documents cited are not readily available from regular sources such as the Defense Documentation Center (DDC) due to the great length of time which has passed since they were written. Copies may be obtained from preparing activities as indicated in the list of references.

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INTRODUCTION

1. Diffioulties with cartridge case plugs have occurred from time to time and have instigated numerous studies. Some studies have been aimed at changing the composition or functioning of cork plugs. Other studies have sought to develop materials or combinations of materials which will provide all the desirable characteristics of design and function and at the same time eliminate or minimize failures under test and service conditions. Apparently, no attempts have been entirely successful.
2. Various materials have been tried and in some cases specifications for procurement and use were written and released. Subsequently, the plugs of materials other than cork were abandoned and cork was once more used exclusively.
3. The chief concern recently has been with cork plugs for 5" guns, particularly those for use in rapid fire 5"/54 guns on Mk 42 Mounts. Properties and specifications for the rapid fire plugs are given in MIL-P-18878 (reference (q)). Of seemingly lesser concern has been plugs for 5"/38 ammunition. These plugs are described in MIL-P-18816 (reference (o)).
4. Failures of cork plugs, typically encountered in recent tests and in service, were noted as early as 1955 (reference (m)), and probably much earlier, although not mentioned in any available report.

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5. The use of other plastics within guns is also mentioned though not in plug applications.

PURPOSE

1. The purposes of this report are (1) to identify the several compositions previously considered, (2) to show that certain materials presently available (notably polyurethane foam) received only transient attention, (3) to make comparisons of polyurethane foam and cork, and (4) to discuss views, comments, and recommendations of individuals interviewed during the literature search. Comparisons (3) and views (4) are included in this report as Appendix A and Appendix B respectively.

CONCLUSIONS

1. Problems with cork cartridge case plugs have been encountered for many years, particularly in periods when ammunition usage rates were high. Several materials other than cork have been tried and at least two have received approval; one was a phenolic resin-cellulose fiber composition (reference (p)) and the other was a phenolic-resin-rubber formulation produced as a foam material with a density of about 16 pounds per cubic foot (references (m) and (n)). The former was used in 5", 6", and 8" gun ammunition but fragmentation problems necessitated discontinuance of use. The latter (foam) was never actually instituted into use, possibly because it was finalized at a time when Naval ammunition was at a low rate of use.
2. The wide range of physical and chemical properties now possible with plastics may warrant careful investigation of one or more families of plastic materials as possible alternatives or substitutes for cork in the production of cartridge case plugs.

HISTORY AND DEVELOPMENTS

1. One of the first non-cork plugs developed is described in MIL-P-18820 (reference (p)). Developed prior to 1946, it was composed of a phenolic plastic resin impregnated cellulose filler conforming to MIL-M-14F (reference (n)), Type CFI-40. These thin-walled Mk 7 Mod 0 plastic plugs failed to meet (reference (i)) certain requirements of OS 757, i.e., when fired, 5" plugs must fragment into particles of 0.5 ounce maximum weight. They also failed ramming tests. Quite similar circumstances have been experienced by the Army with its 120MM semi-fixed ammunition (references (a), (b), (c), (d)) in which M2 and M8 plugs are used (references (t) and (s) respectively). A great deal of redesign work and testing of the Army's plug has been done, but according to Mr. Riedon (reference (rr)), it can be expected that the use of these plugs will be phased out and discontinued.
2. Efforts in redesigning phenolic-pulp plugs of Type CFI 40 material for 8"/55 guns met with only limited success (reference (ff)). From all indications, plugs of the phenolic-pulp type have not been used by the Navy for several years. Efforts to find evidence of use in the last few years were unfruitful.

3. Significant studies of materials for possible use in cartridge case plugs were conducted at the Naval Ordnance Laboratory in the early to middle 1950's (references (i), (j), (k) and (m)).

4. Reference (i) undertook a completely different approach to the material problem. It was considered feasible to employ plastic foams with the correct combination of properties as cartridge case plugs. Consequently, formulations were developed, produced and tested. The formulations selected were principally phenolic resin-rubber blends with other necessary ingredients. By varying the formulation, features such as toughness and fragmentation particle size could be changed.

5. 6"/47 plugs were molded and laboratory tested by appropriate means to simulate ramming tests. The 6"/47 plug was selected because of data available from previous ramming tests of this size cartridge. Results were very satisfactory. Later, plugs of the phenolic resin-rubber foam were tested in a gun and were found satisfactory. 40MM plugs of this material were fired for fragmentation studies. Fragmentation was found to be comparable to the best cork plugs, adequately meeting maximum weight requirements heretofore mentioned.

(Emphasis on the 5"/54 plug was noted in reference (i)).

6. Reference (j) describes several materials and combinations of materials. Tests for comparison of natural cork (no binder), cork compositions with phenolic and vinyl binders as one piece plugs and as case materials with natural cork cores, tire-cord filled phenolic, pulp filled phenolic, and phenolic-rubber compositions were run. Plugs of each different material were ram-tested on the then new Mk 42 Gun Mount. Conditions were adjusted to permit testing at maximum possible stressing, that is, with 1" separation between the case plug and the base of the projectile and 3.25" separation between the rammer spade foot and the base of the cartridge case. Test results indicate that the plug of vinyl plastic-cork outer case with natural cork core performed best. The other plugs were failed for various reasons, principally chipping and breaking. The report recommends further study of the plug indicated as performing best above.

7. Reference (k) covers fragmentation studies on the 5"/54 plug. It details methods for determining fragment size and fragment velocity (based on penetration of targets) at different distances from the gun muzzle. Again, several combinations of materials were tested similar to those compositions mentioned in reference (j). More emphasis was given to

foamed phenolic resin-rubber compositions, however. Fragmentation characteristics were related to standard Mk 3 and Mk 6 cork plugs, and of the plugs containing any plastic material, the foamed phenolic resin-rubber composition produced the lightest particles all of which passed weight requirements of OS 757.

8. Reference (m) is the final report on development of an alternate material. It enumerates difficulties with cork plugs previously referred to within this report and indicates the adoption of a vinyl-resin-cork cased natural cork core plug known as the Mk 9 Mod 0. This plug is described in reference (q) and is in use at the present time. However, the development of improved foamed phenolic resin-rubber occupies most of the report.

9. Different formulations are described and test results given. The most promising formulation of material was made into plugs of various designs for the 5"/54 and later for the 6"/47 and 8"/55 cartridge cases. After completion of formulation and design factors, extensive tests were conducted to determine suitability for service use.

a. Dimensional stability tests were run. Included were outdoor weathering, dry heat, and JAN cycling. Results showed no significant problems. Additional tests were

carried out to ascertain the effects on the plug material when exposed to alcohol and other vapors emanating from propellant materials. Only slight changes in dimensions were noted (no failures).

b. Compatibility studies with the material and various standard propellants were carried out. Surveillance tests with withdrawal of samples exposed to 90°F, 120°F and 150°F for 1, 3, and 6 months showed favorable compatibility characteristics. Standard Taliani tests and KI tests on the propellant indicated no detrimental effects.

c. Fragmentation tests showed a majority of particles of only 0.03 ounces (compared to 0.5 ounce maximum allowable) for a composition with a slightly greater phenolic resin to rubber ratio. Somewhat larger particles may be expected from formulations containing more rubber due to greater toughness and flexibility. The largest particles should still be well below 0.5 ounces each.

d. Physical strength properties were measured and found to be adequate. It was also demonstrated that by changing the rubber part of the formulation to a rubber with lower temperature flexibility, the service temperature of the plug could be correspondingly lowered.

10. Eventually documents were prepared giving specifications for manufacturing and testing of plugs composed of phenolic-

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resin-rubber foam. Specifications for 5"/54 plugs are given in reference (u), for 6"/47 in reference (y), and for 8"/55 in reference (z). Assembly to cartridge cases is also given in references (v), (w) and (x). Plugs of this material were never used, however, although Mr. Ramsdell (reference (uu)), who was involved in most of the testing, recently indicated that he did not know why they haven't been used. Mr. Silver (reference (xx)), who worked on the material development, said that he has no idea why the material was not used. Mr. Silver also expressed the belief that with today's handling practices, plugs of phenolic-resin-rubber foams should be very competitive with cork plugs in price and should display superior performance.

OTHER PLASTICS USED WITHIN GUNS

1. The use of several plastics in various applications within guns has been documented. Nylon, ethyl cellulose, reinforced polyesters, and phenolic nitrile rubber are all mentioned in reference (1). Apparently, no serious problems were encountered. The use of nitrocellulose in the manufacture of gun ammunition is given in references (e), and (f).
2. Polyurethane foam material, with and without additives, has been extensively studied by Picatinny Arsenal (references (go), (dd), and (ee)). Design features of the applications studied have limited the use of polyurethane in those applications but not from a standpoint of incompatibility.
3. Compatibility studies performed at Picatinny Arsenal (reference (h)) show that polyurethane foams are compatible with standard propellants. This was to be expected in view of the very inert (chemical) properties of the polyurethane polymer.
4. As a matter of interest, polyurethane foam received limited consideration as plastic cartridge case plugs in the early 1950's when material investigations were being conducted at the Naval Ordnance Laboratory, White Oak (reference (i)). In those days, the material was known as "alkyd diisocyanate"

foam and the material investigated was only briefly mentioned. Mr. Silver (reference (xx)) recalls that it was dropped from consideration because of low temperature friability and the question of compatibility. He said that since this work was performed in the very early days of polyurethane technology, the question of friability problems then should not preclude the consideration of the material today.

5. For that matter, in the lapse of time since investigations of material took place (references (i), (j), (k) and (m)) in the early 1950's vast improvements and many sophisticated changes can be seen in plastic polymeric materials. The compatibility problem of polyurethane foam with propellants has also been resolved (reference (h)).

APPENDIX A

COMPARISON OF CORK AND POLYURETHANE

1. One of the requirements of the ORD Task under which the literature search was carried out called for a comparison of advantages and disadvantages of polyurethane versus cork plugs. Of course, it is not possible to criticize the two with respect to functioning as cartridge case plugs. Inasmuch as the only incidence of use of polyurethane ("alkyd diisocyanate") foam as a cartridge case plug was made when it was a relatively new material, there is no justification for a true comparison. However, certain other qualities are compared, based on cork in a cork plug and a typical relatively high (8 pounds per cubic foot) density rigid polyurethane foam.

a. Strength qualities - Both materials exhibit greater strength with higher densities, as expected. Particular design features may regulate such properties as compressive strength, tensile strength and shear strength. In the vinyl resin-cork case of the Mk 9 Mod 0 plug the density may be varied by increasing the ratio of vinyl resin to increase the strength. The density of polyurethane foam may be varied from about 1.5 lbs./cu.ft. to about 30 lbs./cu.ft. with corresponding, though not linear, changes in all the strength factors.

b. Functioning temperature - The vinyl resin in the Mk 9 Mod 0 cork plug appears to become brittle in the area of low temperature ramming (+15°F). It tends to soften as 120°F is approached. Rigid polyurethane shows little change in its properties within the range of the two temperature extremes required.

c. Dimensional stability - Very little information is available on the dimensional stability of vinyl-cork as found in the Mk 9 Mod 0 plug. Coefficients of expansion and contraction of polyurethane foam in the temperature use range of cartridge case plugs is about 4.0×10^{-5} inches per inch per degree F. Considering the temperature effects on the metal case also, no problems should arise in combination use.

d. Thermal degradation - In work performed at the Naval Ammunition Depot, Crane, it was found that cork and polyurethane break down at about the same rates and at about the same temperatures. Thermal-Gravimetric Analyses (TGA) were run on samples of cork taken from a Mk 2 Mod 1 plug (for 5"/38) and a sample of 8 pound per cubic foot density polyurethane foam. The results are given in Figures 1, 2, and 3. Figure 4 is a composite graph intended for easier comparison of data. No significant differences in TGA are exhibited.

e. Availability of raw materials - Cork used in cartridge case plugs is all imported. Polyurethane foam raw materials are available from many domestic suppliers, in relatively unlimited quantities.

f. Ease of molding - Observation of forming operation resulting in cork plugs shows many steps and works involved. Conversely, molding polyurethane foam is quite simple and may be limited to only a few steps requiring fewer workers and generally less time than the cork plug. This, combined with an ample supply of readily available raw materials, could encourage more bidders and thus remove cartridge case plugs from the realm of being a sole source item.

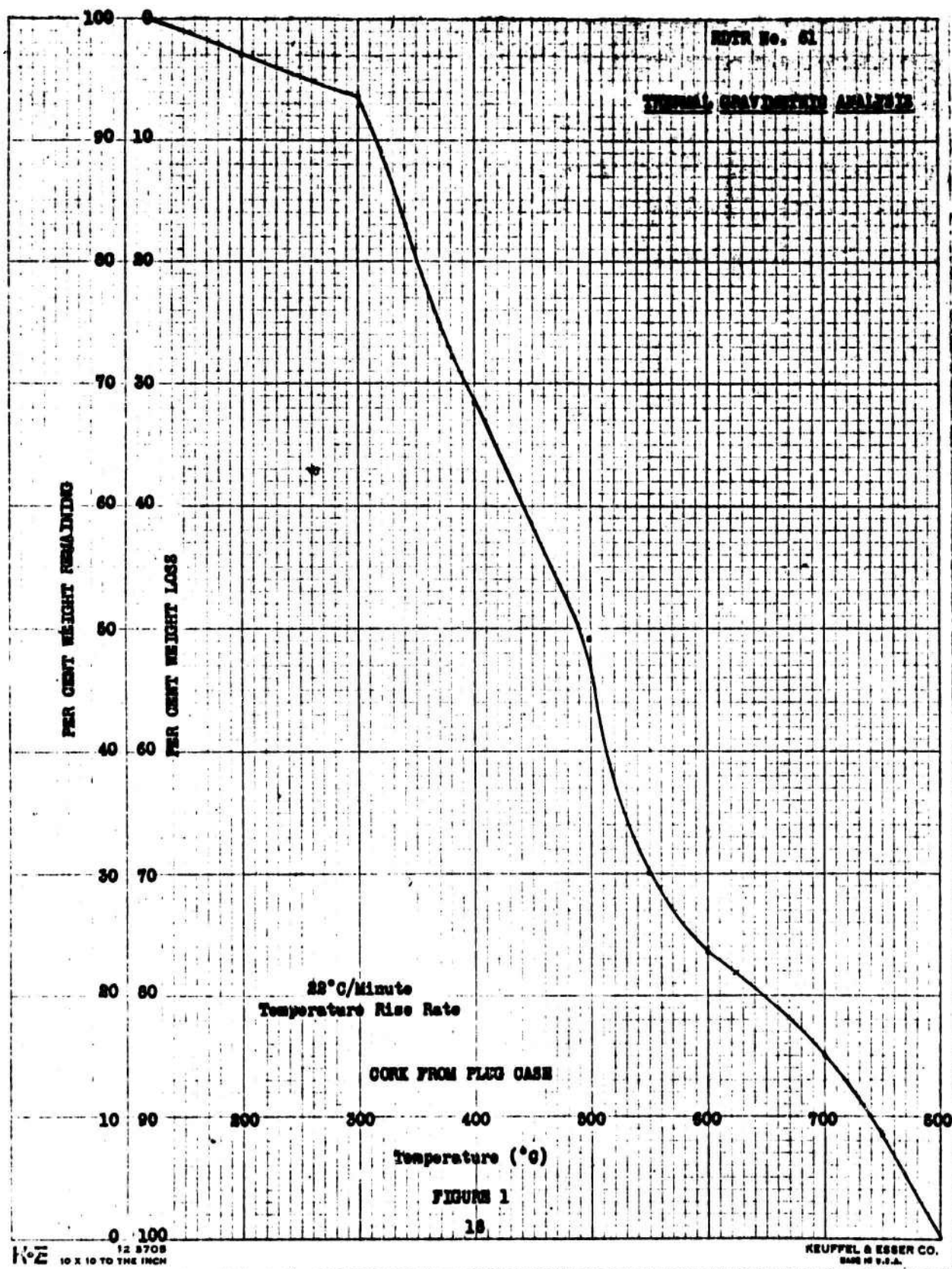
APPENDIX B

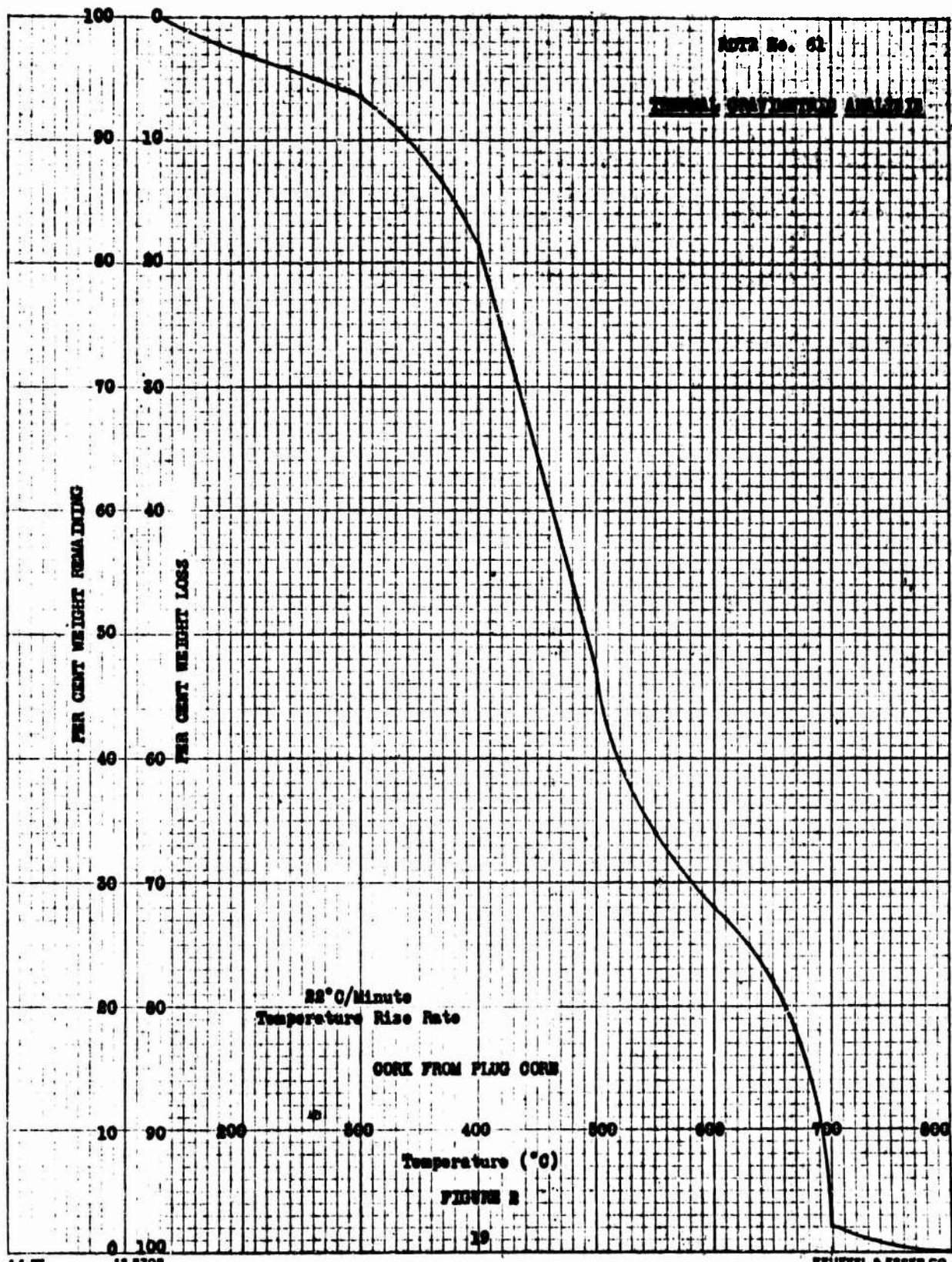
OPINIONS AND RECOMMENDATIONS
OF PERSONS INTERVIEWED

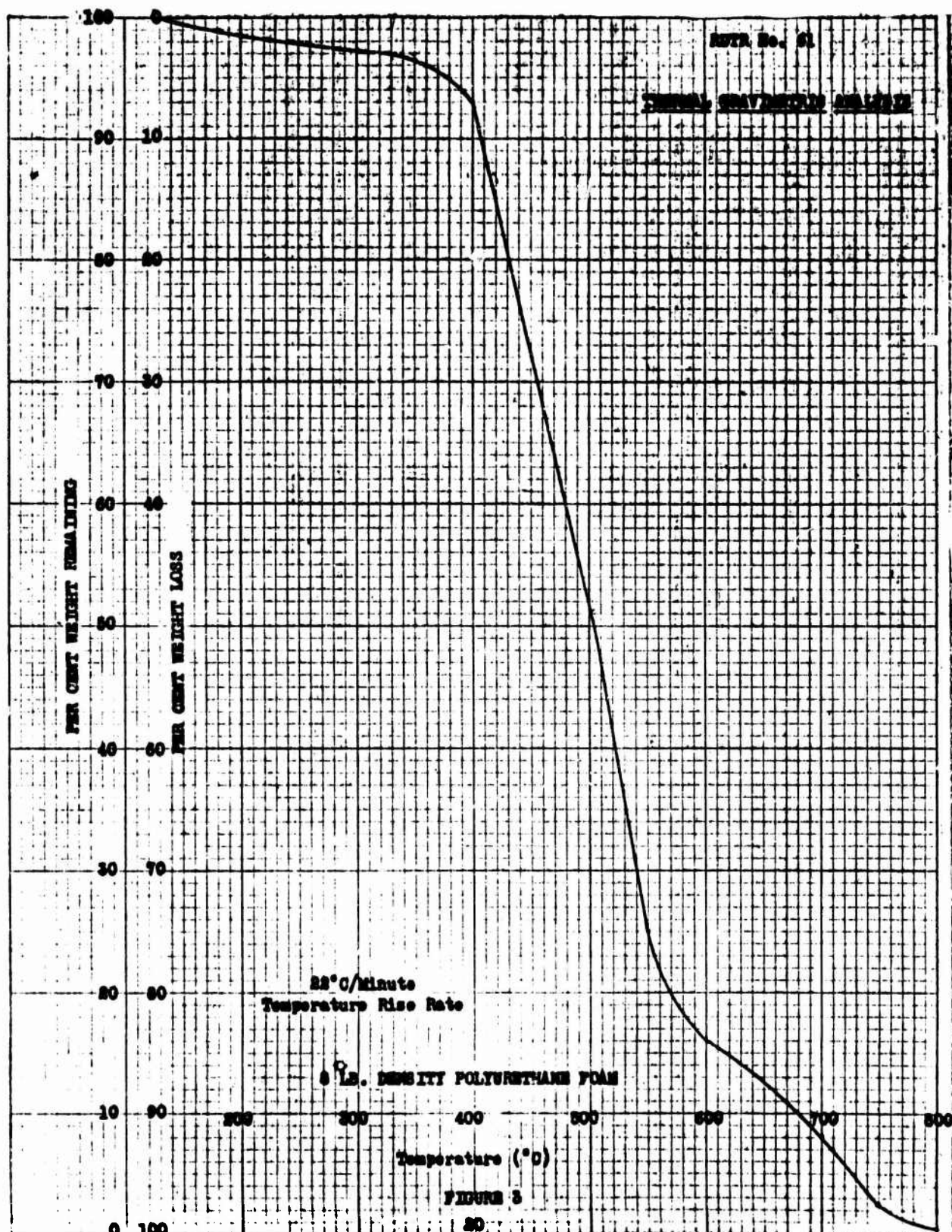
1. The individuals interviewed during the course of this literature search may be divided into two groups: (1) Those who were quite familiar with cartridge case plugs and their performance and (2) persons who were either unfamiliar or only incidentally familiar with cartridge case plugs.
2. Most of those familiar with cork plugs (references (ii), (jj), (ll), (mm), (nn), (pp), (ss), (uu), and (xx)) expressed the belief that good cork plugs were produced once and that they will be again. When questioned about their ideas and attitudes about the possibility of using polyurethane foam molded as cartridge case plugs, they all were optimistic. In addition, most of them favored an investigation of materials as a back-up for cork plugs, with polyurethane foam as a likely candidate.
3. Those unfamiliar with cork plugs (references (kk), (oo), (rr), and (tt)) indicated the attitude that polyurethane foam could be made to fit the set of design criteria established for plugs described by the interviewers.
4. Even the manufacturer of cork plugs (reference (mm)) and his associates (references (nn) and (ii)) readily agreed to

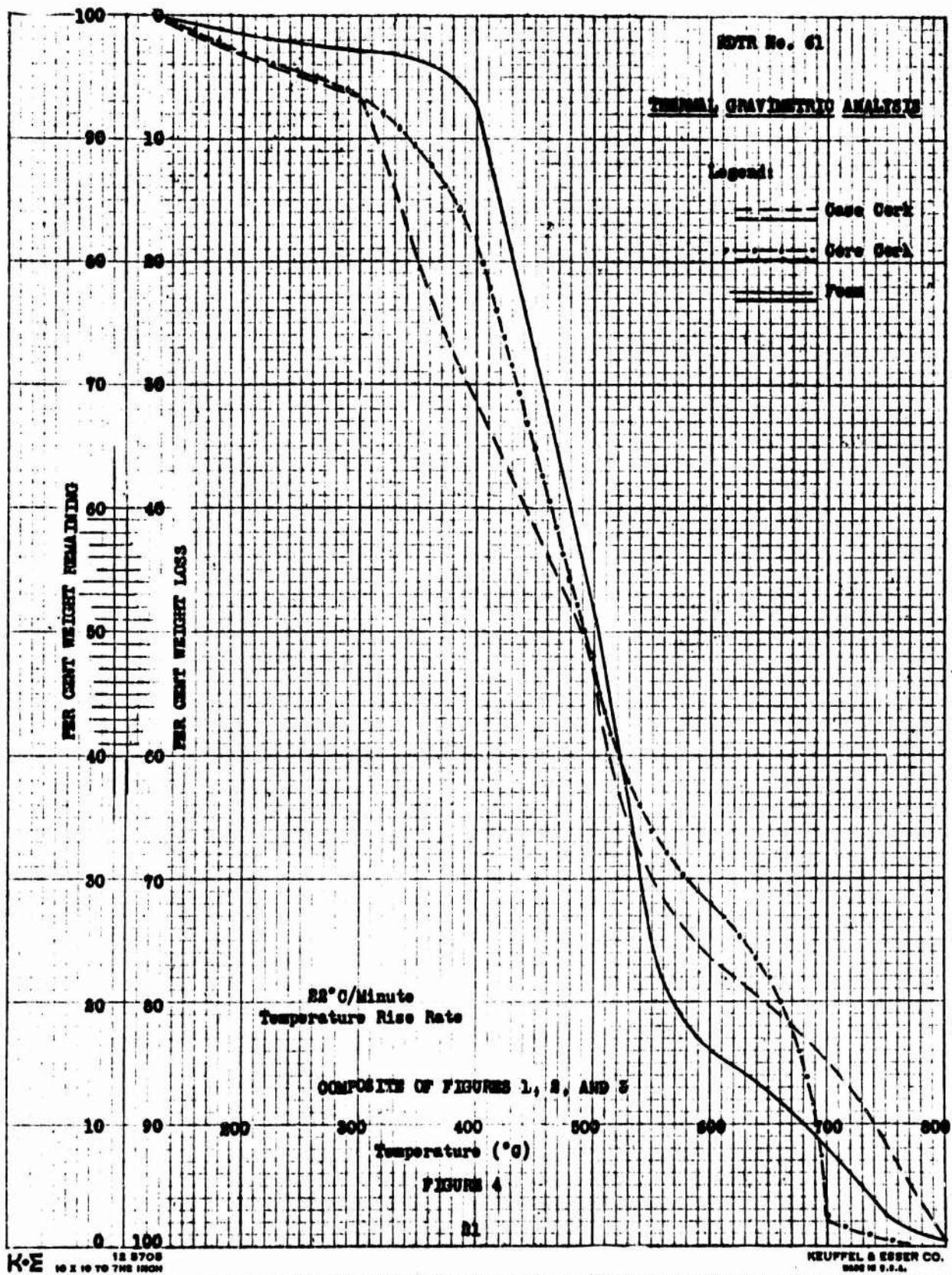
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the merit of having an alternate material approved should cork become unavailable. Reference (mm) expressed the belief that the Mk 9 Mod 0 cork plug's performance at cold ramming could be vastly improved by using a binder in the plug case which did not become brittle in the vicinity of +15°F as does the vinyl resin binder presently specified in reference (q). They also concurred in the belief that polyurethane foam plugs might be produced which would adequately perform in lieu of cork composition cartridge case plugs for Naval ammunition.









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21 Jun 1966
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- (p) MIL-P-18820(NORD) 29 Jun 1955
Plugs, Cartridge Case, Plastic
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ARMY

- (s) Drawing No. 8840530, Plug, Closing, 120MM, M8
- (t) Drawing No. 71-2-128A, Plug, Palmetto Pulp

NAVY

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PERSONAL INTERVIEWS

Reference

- (ii) Mr. John Babbs, Western Molded Fiber Products Co.
- (jj) Mr. F. Robert Barnet, Chief, Non-Metallic Materials Branch, Naval Ordnance Laboratory, White Oak
- (kk) Mr. Edward Costa, Picatinny Arsenal
- (ll) Mr. L. E. Deaton, Ships Parts Control Center, Mechanicsburg, Pa.
- (mm) Mr. P. L. DeLuca, President, Western Molded Fiber Products Co.
- (nn) Mr. Tivo Flores, Western Molded Fiber Products Co.
- (oo) Mr. Harry Graves, Aberdeen Proving Grounds
- (pp) Mr. W. T. Jenkins, Naval Weapons Service Office, Philadelphia, Pa.
- (qq) Mr. Arthur Landrock, PLASTEC, Picatinny Arsenal
- (rr) Mr. William Riedon, Aberdeen Proving Grounds
- (ss) Mr. Glenn Warlick, Naval Propellant Plant, Indian Head, Maryland
- (tt) Mr. Robert Wetton, Picatinny Arsenal

INTERVIEWS BY TELEPHONE

- (uu) Mr. Freeland Ramsdell, Natick Labs., (formerly at NOL, White Oak)
- (xx) Mr. Irvin Silver, NAVAIRSYSCOM (formerly at NOL, White Oak)

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1. ORIGINATING ACTIVITY (Corporate author) U. S. Naval Ammunition Depot Crane, Indiana		2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED
		2b. GROUP
3. REPORT TITLE A LITERATURE SEARCH FOR CARTRIDGE CASE MATERIAL STUDIES		
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Information on material studies as indicated by title from prior to 1946 to present.		
5. AUTHOR(S) (Last name, first name, initial) Smith, Alvin (nmn)		
6. REPORT DATE 8 November 1966	7a. TOTAL NO. OF PAGES 29	7b. NO. OF REFS 34
8a. CONTRACT OR GRANT NO. ORD TASK SSO-002/323/R (PA #9)	9a. ORIGINATOR'S REPORT NUMBER(S) RDTR No. 61	
b. PROJECT NO.		
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	
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10. AVAILABILITY/LIMITATION NOTICES Qualified requesters may obtain copies of this report from DDC.		
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13. ABSTRACT A comprehensive literature search has been carried out to determine whether plastic materials have been used in cartridge case plugs for semi-fixed ammunition and if so, which materials were studied and the results of those studies. Several military activities were visited and numerous personal interviews conducted in an effort to collect all pertinent information associated with cartridge case plug work. A synopsis of findings is given and references are made to applicable documents. Some of the documents cited are not readily available from regular sources such as the Defense Documentation Center (DDC) due to the great length of time which has passed since they were written. Copies may be obtained from preparing activities as indicated in the list of references.		

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3. Foam, Polyurethane							
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